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NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

TECHNICAL NOTE

No. 1240

EFFECT OF SIMULATED SERVICE CONDITIONS ON PLASTICS

By W. A. Crouse, D. C. Caudill, and F. W. Reinhart

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SUMMARY

The effects of simulated service conditions, which involved exposure to various combinations of moisture, heat, and ultraviolet light, on the weight, dimensional stability, and flexural properties of reinforced plastics were investigated. With all factors considered the asbestos-fabric phenolic laminate and the glass-fabric unsaturated-polyester laminate were found to be the most resistant materials of those tested. None of the laboratory aging tests correlated with outdoor weathering with respect to all properties and all materials. Selection of a suitable accelerated test must take into consideration the material to be tested, the property to be investigated, and the service conditions which are to be simulated.

INTRODUCTION

Information regarding the effects of weathering and various temperature and humidity conditions on the properties of laminated plastics is needed to evaluate these materials for use on aircraft and to prepare specifications for the materials that are found suitable for this purpose.

This report presents the results of tests made to determine the effects of outdoor weathering, accelerated weathering, and accelerated service conditions on the weight, dimensions, and flexural properties of nine representative laminated plastics and a macerated-fabric-filled phenolic plastic. The accelerated weathering test involved exposure to cycles of ultraviolet light and fog; the accelerated service tests involved exposure to cycles of various temperatures and relative humidities.

This investigation, conducted at the National Bureau of Standards, was sponsored by and conducted with the financial assistance of the National Advisory Committee for Aeronautics.

MATERIALS

The materials used in this investigation were commercial products, selected to include representative phenolic and unsaturated-polyester plastics which are the types commonly employed in aircraft structures and accessories. The reinforcing fillers in the group of selected plastics included macerated cotton fabric, asbestos, cotton and glass fabrics, and paper. A lignin-paper laminate was also tested as a control on the severity of the tests, because of the known dimensional instability of this type of plastic.

The materials are described in detail in table I. They were obtained in the form of sheets approximately one-eighth inch thick. Since there are appreciable differences in the properties of individual sheets taken from the same batch, in different batches made by the same manufacturer from time to time, and in similar laminates made by different manufacturers, the data reported herein cannot be applied exactly to all samples of the types tested but can be considered only as representative of these types.

TEST SPECIMENS AND PROCEDURES

Specimens

The specimens subjected to the various exposure conditions were 1 inch by 3 inches by the thickness of the sheet. The length and width were machined to within ± 0.005 inch. One surface of each sheet was arbitrarily designated as the reference surface. The specimens of the cloth laminates were cut so that the direction with the greater number of threads per inch in the reference surface was lengthwise. The weight of the specimens varied from approximately 8 to 11 grams.

The specimens were conditioned to approximate weight equilibrium at 77° F and 50-percent relative humidity prior to starting the tests. The periods of time required for the test specimens of the various materials to reach weight equilibrium after the machining operations are given in table II.

Weight and Dimensions

The weight was measured to the nearest milligram, the length to the nearest 0.001 inch, and the width and thickness to the nearest 0.0001 inch. The length was measured at two places and the width and thickness at three places. The changes in weight and dimensions were determined with three specimens of each material.

Flexural Properties

The flexural tests were made in accordance with Method No. 1031 of Federal Specification L-P-406a (reference 1), using the 2400-pound range of a 60,000-pound-capacity hydraulic testing machine shown in figure 1. The flexural apparatus, shown in figures 2 and 3, has been described in reference 2. Load-deflection graphs were obtained in each test on a Southwark-Templin autographic recorder which was operated by a Southwark-Peters plastics extensometer. The 1- by 3-inch specimens exposed to the various test conditions were cut into two 1- by 1.5-inch specimens for the flexural tests. Because of the limited size of the specimens the span-depth ratio was 8:1 instead of 16:1 as prescribed in reference 1. The reference surface of the specimen was on the tension side during the test. The radius of the support and pressure pieces was 1/32 inch. The rate of head separation was 0.01 inch per minute.

The flexural strength and the flexural modulus of elasticity were calculated in accordance with the equations given in Method No. 1031 of reference 1. The maximum deflection for a 1-inch span was calculated by dividing the actual deflection of each specimen by the actual span. The flexural strength values reported are considered to be accurate to 1 percent, the flexural modulus of elasticity values to 3 percent, and the maximum deflection values to 5 percent. All the reported values for flexural properties are the averages obtained with six specimens.

The initial values for the flexural properties were determined on specimens which were heated in a circulating-air oven at 122° F for 48 hours and then conditioned for 48 hours at 77° F and 50-percent relative humidity prior to test. The changes in the flexural strength, flexural modulus of elasticity, and maximum deflection in bending as a result of exposure to the outdoor weathering, accelerated weathering, and accelerated service conditions were calculated from these initial or base values.

Outdoor Weathering

Three sets of three 1- by 3-inch specimens were exposed with the reference surface toward the light on December 7, 1943, on the roof of the Industrial Building, National Bureau of Standards, on racks at an angle of 45° facing south. The specimens were removed from the roof after exposure for 1 year. One set was used for determining flexural properties. Measurements of weight and dimensions were made on another set which was returned to the roof together with the third set for further exposure.

Accelerated Weathering

The accelerated weathering test was made in accordance with Method No. 6021 of reference 1, and involved exposure to cycles of ultraviolet light and a misty atmosphere. The specimens were turned end for end every 24 hours to obtain more uniform exposure to the ultraviolet light over the entire length. The bolts and nuts used for support above the disk were arranged so as to be suitable for holding the 1- by 3-inch specimens.

One set of specimens was used to measure weight and dimensions and another set to determine flexural properties after exposure to accelerated weathering conditions for 120, 240, 360, and 480 hours, respectively. All specimens were reconditioned for 48 hours at 77° F and 50-percent relative humidity after each test period prior to making the measurements.

Accelerated Service Tests

The accelerated service tests were made in accordance with the procedures described in reference 1. The testing conditions included in these methods represent a start toward establishing a group of test procedures for determining the effects of changes of atmospheric temperature and humidity upon plastic products. The significance of these procedures, insofar as correlation with actual service performance is concerned, has not yet been established; however, they are being used by the plastics industry and government agencies in the evaluation and procurement of materials.

The conditions used in the tests were as follows:

Test	Title	Period (hr)	Temperature (°F)	Relative humidity (percent)	Period of conditioning at 77° F and 50-percent relative humidity between cycles (hr)
I	Moderate-temperature test (wet and dry)	24 24	140 140	85 to 90 10	48
II	Moderate-temperature test (dry only)	72	140	10	96
III	Severe-temperature test	24 24	160 160	70 to 75 7	48
IV	High-temperature test	24 24	175 175	95 to 100 5	48
V	High-low temperature test	24 24 24 24	175 -40 175 -40	70 to 75 95 to 100 5 95 to 100	72

It is generally assumed that the order of increasing severity of these tests is as follows: II, I, III, IV, and V.

The specimens were suspended individually over water or saturated aqueous salt solutions in 8-ounce bottles to obtain exposure to the various high relative humidities at elevated temperatures. The relative-humidity values over saturated aqueous salt solutions referred to in this report were taken from reference 3. In each of the five types of tests described in the preceding table, the weight and dimensions of one set of specimens were measured within 10 minutes after the conclusion of each cycle for 10 cycles. Other sets were removed at the end of 5 and 10 cycles, respectively, again conditioned at 77° F and 50-percent relative humidity for 48 hours, and tested for flexural properties.

Moisture Content

The equilibrium moisture content of the Grade C phenolic laminate was determined at several temperatures and relative humidities. The specimens, three for each temperature and relative humidity, were conditioned to approximate weight equilibrium at 77° F and 50-percent relative humidity before the tests were begun. The specimens were suspended in 8-ounce bottles over phosphorus pentoxide, saturated aqueous salt solutions, and water, respectively, depending upon the humidity condition desired.

The equilibrium moisture content was calculated as follows:

$$\text{Moisture content, percent} = \left(\frac{W_e - W_d}{W_d}\right) 100$$

where W_e is the equilibrium weight at the indicated temperature and relative humidity and W_d is the equilibrium weight at 77° F and 0-percent relative humidity. Since the weights of the specimens used to obtain W_d were not the same as those used to obtain the equilibrium weight at the higher humidities, W_d for a specific specimen was calculated as follows:

$$W_d = W_1\left(\frac{W_d}{W_1}\right)_o$$

where W_1 is the equilibrium weight at 77° F and 50-percent relative humidity of the specimen used for a higher humidity test and $\left(\frac{W_d}{W_1}\right)_o$ is the ratio of the equilibrium weights at 77° F and 0-percent relative humidity and 77° F and 50-percent relative humidity, respectively, of the specimen dried over phosphorus pentoxide.

RESULTS AND DISCUSSION

Weight and Dimensional Changes

The changes in weight, length and width, and thickness of the materials upon exposure to the outdoor weathering, accelerated weathering, and accelerated service tests are presented in table III. Some of the results are shown graphically in figures 4 to 6. In most of the tests these changes were negative. Most of the positive changes were in thickness. Considering the magnitude of the changes regardless of sign, accelerated service test IV is the most severe of the test procedures used, accelerated service test II is the next in severity, and outdoor weathering follows as third in severity. Accelerated service test I is the least severe. The paper-base phenolic laminates changed several times more in weight and thickness than the other materials in the outdoor weathering tests.

The relative weight and dimensional stability of the various materials are shown in table V. In this table, the materials are rated according to degree of change, the least change being denoted by a rating of 1. With respect to weight changes, the glass-fabric unsaturated-polyester laminate, E1, was found to be the most stable; followed by the parallel-ply-paper phenolic laminate, B1; the asbestos-fabric phenolic laminate, K1; and the cross-ply-paper phenolic laminate, C1. The most stable material in the length and width was the glass-fabric unsaturated-polyester laminate, E1, followed by the cross-ply-paper phenolic laminate, C1. With respect to thickness changes, the cotton-fabric phenolic laminate, J1, was the most stable, followed by the glass-fabric unsaturated polyester laminate, E1, and the cotton-fabric phenolic laminate, I1.

The laminates tested may be rated from the best to the poorest on the basis of weight and dimensional stability as follows:

Order of quality based on weight and dimensional stability	Material designation	Type of laminate
1	E1	Glass-fabric unsaturated-polyester
2	K1	Asbestos-fabric phenolic
3	B1	Parallel-ply-paper phenolic
4	J1	Cotton-fabric phenolic
5	C1	Crossed-ply-paper phenolic
6	F1	Cotton-fabric unsaturated-polyester
7	I1	Cotton-fabric phenolic
8	H1	Cotton-fabric unsaturated-polyester
9	D1	Lignin paper
10	A1	Macerated cotton-fabric phenolic molding

Changes in Flexural Properties

The changes in flexural strength, flexural modulus of elasticity, and maximum deflection in flexure of the materials upon exposure to the accelerated weathering and accelerated service tests are presented in table IV. The results are shown graphically in figures 7 to 9. The paper and glass-fabric laminates had the highest initial flexural strengths and moduli of elasticity.

The results of the tests showed that there were several cases in which increases in flexural strength resulted from the accelerated weathering and service conditions. These increases in strength were attributed to further cure of the resins. In this connection it is of interest to note that, although further cure of thermosetting resins beyond the amount normally employed usually causes an increase in modulus of elasticity and a decrease in maximum deflection in bending, no such agreement was observed in all cases in the present investigation. Experience shows that after full cure has been reached, further aging results in deterioration of the resin.

Accelerated service test IV is the most severe of the aging procedures with respect to changes in flexural strength. The outdoor weathering and accelerated service test I are about equal and next to text IV in severity. The accelerated weathering test and accelerated service test II are about equal and the least severe of the procedures used.

The relative retention of strength by the various materials is shown in table V. In this table the flexural strength and the flexural modulus of elasticity are rated according to retention of strength, the material with the greatest increase being rated 1 and that with the greatest decrease being rated 11. For maximum deflection in flexure, the material with the greatest negative change is rated as 1 and that with the greatest positive change as 11. The asbestos-fabric phenolic laminate, K1, was the most resistant with regard to retention of flexural strength but it was also the weakest initially; the strength increased on exposure to all the tests. The flexural strengths of all the other materials decreased in one or more of the aging tests. The cotton-fabric phenolic laminate, J1, was second with regard to retention of flexural strength. Considering the retention of flexural modulus of elasticity, the asbestos-fabric phenolic laminate, K1, was the most resistant, followed by the glass-fabric unsaturated-polyester laminate, E1. Considering the effect on deflection in flexure, the cotton-fabric unsaturated-polyester laminate, H1, had the best rating, followed by the cotton-fabric unsaturated-polyester laminate, F1, and the cotton-fabric phenolic laminate, I1.

The laminates tested may be rated from the best to the poorest on the basis of strength retention as follows:

Order of quality based on strength retention	Material designation	Type of laminate
1	K1	Asbestos-fabric phenolic
2	F1	Cotton-fabric unsaturated-polyester
3	E1	Glass-fabric unsaturated-polyester
4	C1	Crossed-ply-paper phenolic
5	I1	Cotton-fabric phenolic
6	J1	Cotton-fabric phenolic
7	H1	Cotton-fabric unsaturated-polyester
8	D1	Lignin paper
9	B1	Parallel-ply-paper phenolic
10	A1	Macerated cotton-fabric phenolic molding

General Resistance

The over-all resistance ratings for the materials were determined by adding the ratings for each property and assigning the material with the lowest sum the over-all rating 1, the next lowest 2, and so forth. The laminates tested may be rated from the best to the poorest on the basis of such over-all resistance as follows:

Order of quality based on over-all resistance	Material designation	Type of laminate
1	K1	Asbestos-fabric phenolic
2	E1	Glass-fabric unsaturated-polyester
3	F1	Cotton-fabric unsaturated-polyester
4	C1	Crossed-ply-paper phenolic
5	J1	Cotton-fabric phenolic
6	I1	Cotton-fabric phenolic
7	B1	Parallel-ply-paper phenolic
8	H1	Cotton-fabric unsaturated-polyester
9	D1	Lignin paper
10	A1	Macerated cotton-fabric phenolic molding

Since the initial flexural properties of the glass-fabric unsaturated-polyester laminate, E1, were superior to those of the asbestos-fabric phenolic laminate, K1, the E1 material was the best of those tested when both stability and maximum strength are considered.

Correlation of Laboratory Aging Tests with Outdoor Weathering

None of the laboratory test procedures can be used with all the materials to obtain changes in properties comparable with changes obtained in outdoor weathering tests. A summary of the results of a detailed comparative tabulation is given in table VI. The results also show that the laboratory evaluation procedure for a specific material or group of materials should be selected by taking into consideration the materials to be tested, the properties to be determined, and the conditions which the materials will meet in service.

Moisture Content

The results of the moisture equilibrium tests on the cotton-fabric phenolic laminate, I1, are reported in table VII and shown graphically in figure 10. These results indicate that equilibrium is reached more rapidly as the temperature is increased. The moisture content decreases as the temperature is increased and increases as the relative humidity is increased. The maximum moisture content observed was 7.1 percent at 77° F and 100-percent relative humidity; 31 weeks were required to reach equilibrium in this case.

The following equation has been found to fit the curves in figure 10 to within 5 percent:

$$M = aR + b(aR)^5$$

where

M moisture content, percent

R relative humidity, percent

and a and b have the following values:

Temperature (°F)	a	b
77	0.0550	0.00032
100	.0510	.00043
140	.0505	.00044
175	.0425	.00167

These constants indicate that the effect of temperature on the equilibrium moisture content was not great between 77° and 175° F at low relative humidities and between 77° and 140° F at high relative humidities. However, the effect of temperature between 140° and 175° F at high humidities was more pronounced.

The point at 100° F and 100-percent relative humidity does not agree with the general pattern indicated by the other points as shown in figure 10. This point was redetermined with three additional specimens; the second determination agreed within 4 percent of the first determination. No reason for this apparent discrepancy is known.

CONCLUSIONS

None of the laboratory aging tests gave results with all the materials and for all the properties which correlated with the results of outdoor weathering. A laboratory evaluation procedure for a material or group of materials should be selected on the basis of the materials, the properties to be determined, and the conditions which the materials will meet in service.

Accelerated service test IV, consisting in alternate exposure for 24 hours at 175° F and 95- to 100-percent relative humidity followed by 24 hours at 175° F and a relative humidity less than 5 percent, was the most severe of those used in this investigation. All the materials except the asbestos-fabric phenolic laminate, K1, increased in thickness in this test. This material was the only one which increased in flexural strength and flexural modulus of elasticity on exposure to accelerated service test IV.

The asbestos-fabric phenolic and glass-fabric unsaturated-polyester laminates were the most resistant of the materials tested. The paper-base phenolic laminates were not so stable in weight and thickness after outdoor weathering as the other materials tested. These results indicate that the most resistant laminates are those made with materials which are least affected by water.

The equilibrium moisture content for cotton-fabric phenolic laminate decreased with an increase in temperature and a decrease in relative humidity. The time for attainment of equilibrium decreased with an increase in temperature. The temperature effect on the equilibrium moisture content was not so pronounced between 77° and 175° F at low relative humidities and between 77° and 140° F at high relative humidities as it was between 140° and 175° F at high relative humidities.

National Bureau of Standards,
Washington, D. C., September 13, 1946.

REFERENCES

1. Federal Specification L-P-406a: Plastics, Organic; General Specifications, Test Methods; Jan. 24, 1944. Government Printing Office, Washington 25, D. C.

2. Lamb, J. J., Albrecht, Isabelle, and Axilrod, B. M.: Impact Strength and Flexural Properties of Laminated Plastics at High and Low Temperatures. NACA TN No. 1054, 1946.

3. Washburn, Edward W., Ed.-in-Chief: International Critical Tables of Numerical Data, Physics, Chemistry, and Technology. First ed. McGraw-Hill Book Co., Inc., (New York): vol. 1, 1926, p. 67.

Table I.- Description of Materials

NBS Material Designation	Type of Laminate/a	Manufacturer	Thickness, Average (in.)	Density (g/cm³)	Resin: Type	Resin: Content, by Weight (percent)	Reinforcement: Type	Reinforcement: Thread Count, Warp	Reinforcement: Thread Count, Filling	Reinforcement: Ply Arrangement	Reinforcement: No. of Plies	Molding Conditions: Pressure (lb/in²)	Molding Conditions: Curing Temperature, Initial (°F)	Molding Conditions: Curing Temperature, Maximum (°F)	Molding Conditions: Time, Curing (min)	Molding Conditions: Time, Cooling (min)
A1	Macerated-Cotton-Fabric Phenolic Molding Compound	Bakelite Corp.	0.121	1.37	Bakelite BM-199		Macerated Cotton Fabric	—	—	———		2100	250	320	15	5
B1	High Strength-Paper, Phenolic	Consolidated Water Power and Paper Co.	0.121	1.43			Paper	—	—	Parallel		250				
C1	High-Strength-Paper, Phenolic	Consolidated Water Power and Paper Co.	0.124	1.43			Paper	—	—	Crossed		250				
D1	Lignin Paper	Formica Insulation Co.	0.128	1.38	Lignin		Lignin Paper	—	—							
E1	Glass-Fabric, Unsaturated Polyester	Swedlow Aeroplastics Corp.	0.116	1.70	Marco MR-1A		Glass Fabric, plain weave ECG-11-162	29	17	Crossed	7					
F1	Muslin-Cotton-Fabric, Unsaturated Polyester	Swedlow Aeroplastics Corp.	0.131	1.27	Marco MR-1A		Cotton Fabric (Muslin), twill weave	70	48		7					
H1	Enameled-Duck Cotton-Fabric, Unsaturated Polyester	Pittsburgh Plate Glass Co., Columbia Chemical Division	0.145	1.37	Allymer CR39	60-65	Cotton Fabric (Enameled Duck), plain weave	36	32	Crossed	6	1-5	158	239	2 Hours at 158°F, 10 Hours at 158-239°F	Gradual
I1	Grade C Phenolic	Synthane Corp.	0.122	1.36	Bakelite No. 1112	48	Cotton Fabric, plain weave, 10 oz/yd²	50	40	Crossed	7	1800		340	50	20
J1	Grade L Phenolic	Synthane Corp.	0.125	1.34	Bakelite BV-1112	45-50	Cotton Fabric, plain weave, 3.7 oz/yd²	80	80	Parallel	19	1600		320	45	25
K1	Grade AA Phenolic	Synthane Corp.	0.149	1.90	Bakelite No. 8427	47	Asbestos Fabric, plain weave, 18 oz/yd²	18	16	Parallel	5	1800		340	50	20

/a Material A1 was obtained in the form of sheets prepared from a molding compound; all of the other materials were laminated sheet products.

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TABLE II.– CONDITIONING OF PLASTIC SPECIMENS TO WEIGHT EQUILIBRIUM

AT 77° F AND 50-PERCENT RELATIVE HUMIDITY

Material designation	Approximate time to reach 50 percent of equilibrium	Approximate time to reach 75 percent of equilibrium	Approximate time to reach 90 percent of equilibrium	Approximate time to reach equilibrium	Increase in weight at equilibrium (percent)
A1	16 days	7 weeks	10 weeks	15 weeks	0.49
[a]B1	8 weeks	16 weeks	25 weeks	52 weeks	1.35
[b]B1	6 weeks	13 weeks	22 weeks	32 weeks	1.10
C1	7 weeks	14 weeks	25 weeks	52 weeks	1.23
D1	12 days	31 days	8 weeks	11 weeks	.59
E1	2 days	5 days	7 days	4 weeks	.07
F1	6 days	13 days	40 days	9 weeks	.41
H1	7 days	21 days	36 days	9 weeks	.45
I1	12 days	27 days	56 days	14 weeks	.66
J1	12 days	7 weeks	11 weeks	16 weeks	.76
K1	———	———	———	[c]52 weeks	[c].65

[a]Specimens cut lengthwise.
[b]Specimens cut crosswise.
[c]Not at equilibrium after 1 year.

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TABLE III.- CHANGES IN WEIGHT AND DIMENSIONS OF PLASTICS DURING OUTDOOR WEATHERING, ACCELERATED WEATHERING, AND ACCELERATED SERVICE TESTS.

Material Designation	Change During Outdoor Weathering Test	Changes During Accelerated Weathering Test				Changes During Accelerated Service Test No. I				Changes During Accelerated Service Test No. II			
	1 Year (%)	120 Hours (%)	240 Hours (%)	360 Hours (%)	480 Hours (%)	1 Cycle (%)	3 Cycles (%)	5 Cycles (%)	10 Cycles (%)	1 Cycle (%)	3 Cycles (%)	5 Cycles (%)	10 Cycles (%)
						W E I G H T							
A1	-0.85	-2.12	-2.46	-2.38	-2.47	-1.80	-2.52	-2.79	-3.19	-1.81	-2.57	-3.04	-3.53
B1[a]	1.39	-0.77	-1.15	-1.34	-1.42	-0.28	-0.14	-0.06	-0.04	-1.08	-1.55	-1.84	-2.24
B1[b]	1.45	-0.86	-1.24	-1.35	-1.57	-0.34	-0.21	-0.16	-0.16	-1.10	-1.59	-1.86	-2.25
C1	1.44	-0.85	-1.24	-1.43	-1.54	-0.37	-0.26	-0.23	-0.21	-1.18	-1.72	-2.03	-2.45
D1	-0.11	-1.73	-2.19	-2.35	-2.45	-0.80	-0.89	-0.93	-1.00	-1.32	-1.88	-2.17	-2.49
E1	-0.33	-0.15	-0.17	-0.18	-0.20	-0.06	-0.07	-0.10	-0.10	-0.30	-0.31	-0.35	-0.40
F1	-0.44	-1.09	-1.29	-1.29	-1.33	-0.80	-0.97	-1.05	-1.19	-1.37	-1.58	-1.69	-1.83
H1	-0.38	-1.20	-1.39	-1.46	-1.56	-0.74	-0.90	-1.01	-1.19	-1.43	-1.64	-1.77	-1.94
I1	-0.78	-1.91	-2.16	-2.13	-2.37	-1.61	-1.97	-2.01	-2.15	-1.60	-2.10	-2.32	-2.52
J1	-0.43	-1.24	-1.60	-1.71	-1.79	-0.93	-1.15	-1.25	-1.39	-1.10	-1.59	-1.87	-2.17
K1	-0.44	-0.93	-0.92	-0.75	-0.62	-0.89	-0.98	-0.94	-0.90	-1.24	-1.15	-1.12	-0.85
						L E N G T H A N D W I D T H							
A1	-0.08	-0.27	-0.34	-0.22	-0.22	-0.06	-0.22	-0.25	-0.38	-0.21	-0.32	-0.36	-0.41
B1[a]	-0.14	-0.08	-0.12	-0.08	-0.08	-0.05	-0.06	-0.06	-0.06	-0.08	-0.12	-0.14	-0.18
B1[b]	-0.23	-0.06	-0.08	-0.08	-0.12	-0.07	-0.09	-0.09	-0.10	——	-0.12	-0.12	-0.16
C1	-0.14	-0.08	-0.12	-0.06	-0.08	-0.07	-0.06	-0.07	-0.08	-0.06	-0.10	-0.10	-0.13
D1	-0.12	-0.25	-0.32	-0.28	-0.30	-0.11	-0.13	-0.14	-0.14	-0.16	-0.24	-0.27	-0.32
E1	0.06	-0.04	-0.06	-0.02	0.03	-0.01	-0.04	-0.02	-0.04	-0.02	-0.04	-0.02	-0.03
F1	-0.20	-0.19	-0.24	-0.12	-0.12	-0.08	-0.10	-0.08	-0.10	-0.16	-0.20	-0.21	-0.22
H1	-0.25	-0.27	-0.32	-0.27	-0.30	-0.16	-0.22	-0.22	-0.26	-0.22	-0.24	-0.26	-0.30
I1	-0.10	-0.30	-0.36	-0.30	-0.30	-0.12	-0.17	-0.18	-0.20	-0.18	-0.26	-0.28	-0.32
J1	-0.08	-0.18	-0.22	-0.18	-0.19	-0.07	-0.12	-0.09	-0.12	-0.12	-0.18	-0.22	-0.24
K1	-0.09	-0.16	-0.20	-0.15	-0.14	-0.06	-0.08	-0.08	-0.10	-0.10	-0.10	-0.10	-0.11
						T H I C K N E S S							
A1	0.48	-0.48	-0.76	-0.33	-0.69	-0.43	-0.07	-0.05	-0.88	-0.36	-0.51	-0.66	-0.70
B1[a]	3.51	-0.30	-0.91	-0.82	-0.73	0.16	0.63	0.64	1.01	-0.54	-1.06	-1.33	-1.52
B1[b]	3.82	-0.21	-0.46	-0.54	-0.81	0.25	0.63	1.01	1.23	-0.54	-1.04	-1.17	-1.44
C1	3.20	-0.57	-1.08	-1.19	-1.03	0.22	0.41	0.63	0.68	-0.62	-1.27	-1.49	-1.71
D1	0.57	-0.76	-1.15	-1.20	-1.14	-0.11	0.13	0.13	0.21	-0.34	-0.72	-0.82	-0.98
E1	0.43	0.14	0.00	0.20	0.59	-0.12	-0.18	0.05	-0.13	-0.20	-0.20	-0.14	-0.03
F1	1.22	-0.57	-1.03	-0.57	-0.52	-0.10	0.08	0.30	0.30	-0.56	-0.56	-0.67	-0.59
H1	0.50	-0.41	-0.26	-0.26	-0.76	-0.05	0.09	0.44	0.28	-0.31	-0.40	-0.23	-0.21
I1	-0.19	-0.32	-0.51	-0.32	-0.21	-0.40	-0.21	-0.11	-0.11	-0.21	-0.32	-0.29	-0.19
J1	0.11	-0.26	-0.50	-0.32	-0.29	0.06	-0.08	0.00	-0.05	-0.29	-0.35	-0.37	-0.38
K1	-0.45	-0.80	-0.45	-0.36	-0.38	-0.02	0.02	-0.09	-0.15	-0.23	-0.28	-0.21	-0.14

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a. Specimens cut lengthwise
b. Specimens cut crosswise

TABLE III.- CONCLUDED.

Material Designation	Changes During Accelerated Service Test No. III: 1 Cycle (%)	3 Cycles (%)	5 Cycles (%)	10 Cycles (%)	Changes During Accelerated Service Test No. IV: 1 Cycle (%)	3 Cycles (%)	5 Cycles (%)	10 Cycles (%)	Changes During Accelerated Service Test No. V: 1 Cycle (%)	3 Cycles (%)	5 Cycles (%)	10 Cycles (%)
WEIGHT												
A1	-2.25	-3.32	-3.67	-4.28	-4.32	-4.73	-4.91	-5.13	0.85	-3.42	-3.96	-3.92
B1a	-0.57	-0.50	-0.33	-0.42	0.12	0.40	0.39	0.16	1.51	-0.61	-0.73	-0.54
B1b	-0.63	-0.65	-0.57	-0.68	-0.01	0.16	0.14	-0.11	1.19	-0.87	-1.00	-0.74
C1	-0.73	-0.82	-0.80	-0.92	-0.13	0.12	0.11	-0.19	1.09	-0.98	-1.15	-0.95
D1	-1.11	-1.41	-1.44	-1.62	-1.79	-2.24	-2.45	-2.81	0.60	-1.71	-1.89	-1.64
E1	-0.28	-0.33	-0.34	-0.42	-0.38	-0.73	-0.92	-1.10	0.31	-0.27	-0.29	-0.34
F1	-1.21	-1.38	-1.36	-1.58	-2.10	-2.45	-2.64	-3.13	1.05	-1.50	-1.48	-1.55
H1	-1.16	-1.41	-1.46	-1.78	-1.62	-2.05	-2.36	-2.80	0.90	-1.83	-2.09	-2.10
I1	-1.79	-2.28	-2.35	-2.65	-1.96	-2.31	-2.59	-2.90	0.51	-2.26	-2.45	-2.25
J1	-1.05	-1.45	-1.58	-1.77	-1.71	-2.01	-2.32	-2.66	0.56	-1.76	-1.98	-1.83
K1	-1.19	-1.34	-1.35	-1.40	-1.55	-1.62	-1.75	-1.76	0.70	-0.61	-0.75	-0.51
LENGTH AND WIDTH												
A1	-0.15	-0.27	-0.34	-0.41	-0.40	-0.36	-0.37	-0.44	0.10	-0.40	-0.53	-0.56
B1a	-0.06	-0.07	-0.07	-0.09	-0.18	-0.16	-0.17	-0.19	0.02	-0.10	-0.12	-0.12
B1b	-0.07	-0.08	-0.10	-0.10	-0.18	-0.13	-0.14	-0.18	0.02	-0.12	-0.13	-0.12
C1	-0.04	-0.07	-0.07	-0.08	-0.13	-0.12	-0.10	-0.14	0.00	-0.10	-0.12	-0.10
D1	-0.14	-0.20	-0.20	-0.22	-0.50	-0.58	-0.66	-0.75	0.04	-0.25	-0.28	-0.28
E1	-0.02	-0.02	-0.02	-0.04	0.13	0.10	0.08	0.06	0.03	0.00	-0.02	-0.01
F1	-0.14	-0.20	-0.22	-0.26	-0.32	-0.37	-0.40	-0.48	0.01	-0.26	-0.29	-0.34
H1	-0.20	-0.26	-0.31	-0.38	-0.22	-0.32	-0.36	-0.46	0.02	-0.36	-0.44	-0.47
I1	-0.22	-0.28	-0.30	-0.38	-0.23	-0.27	-0.32	-0.36	0.02	-0.30	-0.34	-0.34
J1	-0.08	-0.14	-0.18	-0.19	-0.20	-0.24	-0.28	-0.32	0.03	-0.22	-0.26	-0.26
K1	-0.08	-0.20	-0.16	-0.18	-0.10	-0.14	-0.17	-0.22	0.02	-0.13	-0.16	-0.18
THICKNESS												
A1	-0.30	-0.64	-0.63	-0.79	1.54	3.09	3.77	4.05	0.73	-0.54	-0.71	-0.71
B1a	-0.06	0.22	0.03	0.08	1.54	2.75	2.88	2.99	1.46	0.35	0.35	0.60
B1b	-0.17	0.08	0.11	0.11	1.30	2.78	2.94	3.13	1.24	0.05	-0.16	0.08
C1	-0.16	-0.03	-0.08	-0.30	1.03	2.53	2.42	2.69	1.09	-0.16	-0.35	-0.16
D1	-0.13	-0.16	-0.26	-0.26	2.34	2.55	2.78	3.49	0.60	-0.26	-0.34	-0.23
E1	0.07	0.28	0.03	0.21	1.00	0.73	0.68	0.35	0.03	-0.09	-0.06	0.17
F1	-0.03	0.00	-0.13	-0.16	1.12	1.25	1.57	1.85	0.78	-0.18	-0.18	0.02
H1	0.09	0.09	0.28	0.08	-0.16	0.83	0.18	0.24	0.66	-0.07	-0.07	0.25
I1	-0.19	-0.19	-0.13	-0.13	0.49	0.60	0.68	0.81	0.19	-0.27	-0.19	-0.05
J1	0.11	0.05	0.03	-0.21	0.61	0.64	0.56	0.69	0.40	-0.08	-0.13	0.03
K1	-0.14	-0.22	-0.20	-0.28	0.02	-0.14	-0.16	-0.25	0.30	-0.07	-0.09	-0.13

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a. Specimens cut lengthwise.
b. Specimens cut crosswise.

TABLE IV.- CHANGES IN FLEXURAL STRENGTH, MODULUS OF ELASTICITY, AND MAXIMUM DEFLECTION IN FLEXURE OF PLASTICS DURING OUTDOOR WEATHERING, ACCELERATED WEATHERING, AND ACCELERATED SERVICE TESTS.

Material Designation	Initial Strength, Modulus, or Deflection	Change During Outdoor Weathering Test	Change During Accelerated Weathering Test				Change During Accelerated Service Test I		Change During Accelerated Service Test II		Change During Accelerated Service Test III		Change During Accelerated Service Test IV		Change During Accelerated Service Test V	
		1 Year (%)	120 Hours (%)	240 Hours (%)	360 Hours (%)	480 Hours (%)	5 Cycles (%)	10 Cycles (%)	5 Cycles (%)	10 Cycles (%)	5 Cycles (%)	10 Cycles (%)	5 Cycles (%)	10 Cycles (%)	5 Cycles (%)	10 Cycles (%)
							FLEXURAL STRENGTH									
	(lb/in²)															
A1	12,700	2.4	-4.7	-5.5	-6.9	0.0	-12.6	-21.5	5.5	-0.8	-16.5	-7.1	-25.6	-41.6	-14.2	-16.9
B1[a]	42,600	-22.4	-4.5	0.7	-0.2	-2.4	-12.4	-12.9	7.8	8.9	-4.2	-11.7	-13.5	-24.2	-1.9	-4.9
B1[b]	29,000	-22.1	3.8	2.4	-0.8	0.0	-11.0	-13.8	5.9	5.9	-6.9	-15.2	-22.1	-23.1	2.4	-4.1
C1	25,100	-26.5	6.3	4.6	7.1	8.6	-5.4	-11.1	10.5	10.8	1.1	1.4	-17.7	-17.1	2.8	-0.3
D1	23,500	-14.5	-1.7	8.0	8.0	8.0	-8.5	-6.4	3.0	3.0	-8.9	-6.8	-20.8	-20.6	-5.1	-11.9
E1	24,100	0.0	0.0	2.8	13.5	22.9	-9.1	-9.1	-15.2	-12.6	-0.8	6.2	-9.7	-14.1	-0.9	-1.2
F1	16,100	-24.8	4.4	5.6	-2.5	-5.6	1.2	0.6	3.1	-0.6	-8.1	-4.5	-19.9	-25.5	0.0	-14.3
H1	13,100	-5.3	-8.8	-6.9	-13.7	-13.7	-4.6	-5.8	-8.8	-3.8	-6.9	-13.7	-14.5	-26.9	-12.2	-19.8
I1	22,900	-6.3	-3.9	-3.1	-6.6	-3.1	-3.1	-5.5	-0.9	-2.6	-5.2	-5.7	-14.4	-15.3	-4.8	-8.7
J1	17,400	-11.5	-4.6	0.0	-2.3	-3.4	2.8	2.9	27.9	34.5	1.7	-2.9	-11.5	-13.8	-2.3	-15.5
K1	9,000	17.8	11.1	15.6	11.1	15.6	12.2	7.7	17.8	16.7	13.3	9.1	4.2	6.1	13.3	6.0
							MODULUS OF ELASTICITY IN FLEXURE									
	(lb/in²)															
A1	1,170,000	-26.1	-27.1	-27.4	-28.8	-20.2	-27.2	-26.9	-14.4	-16.8	-45.5	-43.7	-65.8	-74.8	-44.6	-46.0
B1[a]	3,858,000	-27.4	-11.8	-12.7	-5.9	-5.4	-16.6	-18.0	-6.4	-1.4	-12.7	-16.4	-25.1	-28.8	-12.8	-12.8
B1[b]	1,845,000	-32.1	-7.3	-2.9	-7.6	-5.8	-16.9	-22.4	-5.7	-0.6	-23.6	-26.4	-26.2	-29.1	-16.1	-16.1
C1	2,567,000	-24.6	-4.6	-4.3	-6.3	-5.0	-11.2	-16.2	0.5	1.0	-19.5	-16.7	-25.5	-30.5	-9.7	-10.5
D1	1,980,000	-11.8	-6.1	-4.5	-1.0	-8.6	-11.7	-14.6	-4.5	-1.0	-17.8	-18.1	-25.4	-42.4	-11.4	-12.4
E1	1,810,000	-2.2	-6.6	5.1	3.8	9.0	-5.2	-7.0	-20.6	-12.0	0.4	0.9	-19.1	-23.0	7.6	-3.2
F1	706,000	-12.6	4.7	13.0	0.8	-0.7	-12.8	-15.2	0.4	6.8	-15.2	-11.6	-23.6	-39.7	-0.8	-20.1
H1	952,000	-13.2	-9.2	-14.4	-17.2	-17.0	-12.8	-15.8	-11.7	-7.1	-19.6	-14.9	-27.6	-31.1	-22.4	-22.6
I1	1,236,000	-15.5	-7.1	-9.0	-7.8	-4.2	-13.2	-14.7	-7.4	-4.6	-20.4	-15.7	-31.0	-36.4	-13.5	-12.1
J1	1,121,000	-26.6	-17.6	-15.2	-16.9	-15.2	-21.7	-25.4	14.3	17.5	-26.5	-24.5	-40.8	-47.2	-27.8	-23.5
K1	986,000	9.1	10.8	2.8	-14.8	-11.2	6.0	9.4	2.6	-0.8	-0.8	6.7	-4.0	4.9	7.4	9.1
							MAXIMUM DEFLECTION IN FLEXURE									
	(mils)															
A1	24.0	34.3	24.6	14.8	57.1	1.7	39.2	49.2	11.7	6.7	46.3	59.2	112.1	125.4	36.2	52.1
B1[a]	26.4	1.1	-7.6	-2.6	-6.4	-4.0	17.4	13.6	5.7	5.7	10.2	-7.2	21.2	28.0	6.1	5.2
B1[b]	31.0	15.6	16.4	5.5	1.9	-0.6	24.2	26.4	4.8	6.6	18.4	35.6	34.7	35.8	21.3	6.4
C1	27.4	6.9	12.4	-1.8	9.1	11.3	19.3	10.2	5.1	1.8	18.2	17.2	17.5	21.8	5.5	5.5
D1	21.5	-3.3	5.3	8.4	2.8	2.3	3.2	8.8	7.4	4.2	2.3	4.6	25.1	15.7	2.8	-3.1
E1	45.7	-1.1	16.4	3.8	-1.3	-4.4	0.0	17.1	54.3	45.7	27.4	-4.2	54.5	56.5	-15.5	0.7
F1	72.7	-40.8	-14.0	-23.4	-24.9	-25.2	24.5	13.7	-14.6	-25.4	-1.4	-4.8	2.5	5.1	-19.8	-17.8
H1	66.2	-10.4	-22.7	-28.4	-26.7	-26.8	-1.2	-6.8	-10.7	-10.6	-5.6	-25.5	-5.8	-26.2	-21.7	-20.5
I1	65.2	5.4	-12.4	-9.0	-16.6	-15.0	5.2	2.2	-9.4	-15.2	-2.8	-0.3	2.4	9.2	-9.4	-17.3
J1	41.2	-5.8	-9.7	-1.9	-3.6	-11.9	14.8	15.5	-4.8	-11.6	8.7	5.6	15.7	27.9	0.0	-21.8
K1	21.0	7.1	-0.5	0.0	11.9	9.0	-1.4	-5.7	4.8	-1.0	8.6	-6.7	11.9	-6.2	-4.8	-7.1

a. Specimens cut lengthwise.

b. Specimens cut crosswise.

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TABLE V.- RESISTANCE RATINGS[a] OF THE PLASTIC MATERIALS IN OUTDOOR WEATHERING, ACCELERATED WEATHERING, AND ACCELERATED SERVICE TESTS

Material Designation	WEIGHT								LENGTH AND WIDTH								THICKNESS							
	Weathering		Accelerated Service Tests					Over-all Rating	Weathering		Accelerated Service Tests					Over-all Rating	Weathering		Accelerated Service Tests					Over-all Rating
	Out-door	Accel-erated	I	II	III	IV	V		Out-door	Accel-erated	I	II	III	IV	V		Out-door	Accel-erated	I	II	III	IV	V	
	1 yr	180 hr	5 cy	5 cy	5 cy	5 cy	5 cy		1 yr	180 hr	5 cy	5 cy	5 cy	5 cy	5 cy		1 yr	180 hr	5 cy	5 cy	5 cy	5 cy	5 cy	
A1	8	11	11	11	11	11	11	11	2.5	9.5	11	11	11	9	11	10	3	7	2.5	6	11	11	11	7
B1[b]	9	2	1	5	1	3	2	2	7.5	3.5	2	5	2.5	4.5	2.5	3	10	4	10	10	2	9	9.5	9
B1[c]	11	4	3	6	3	2	4	4	10	2	6.5	4	4	3	4	5	11	2	11	9	5	10	5	8
C1	10	3	4	8	4	1	5	5	7.5	3.5	3	2.5	2.5	2	2.5	2	9	8.5	9	11	4	7	9.5	11
D1	1	9	5	9	7	8	7	8	6	8	8	9	7	11	7	8	7	10	6	8	9	8	8	10
E1	2	1	2	1	2	4	1	1	1	1	1	1	1	1	1	1	4	1	2.5	1	3	4.5	1	1
F1	5.5	6	8	3	6	10	6	6	9	7	4.5	6	8	10	8	7	8	8.5	7	7	6.5	6	6	6
H1	3	7	7	4	8	7	9	7	11	9.5	10	8	10	8	10	11	6	6	8	3	10	2	2	5
I1	7	10	10	10	10	9	10	10	5	11	9	10	9	7	9	9	2	5	5	4	6.5	4.5	7	3.5
J1	4	8	9	7	9	6	8	9	2.5	6	6.5	7	6	6	6	6	1	3	1	5	2	3	4	2
K1	5.5	5	6	2	5	5	3	3	4	5	4.5	2.5	5	4.5	5	4	5	11	4	2	8	1	3	3.5
	1 yr	240 hr	10 cy	10 cy	10 cy	10 cy	10 cy		1 yr	240 hr	10 cy	10 cy	10 cy	10 cy	10 cy		1 yr	240 hr	10 cy	10 cy	10 cy	10 cy	10 cy	
A1	8	11	11	11	11	11	11	11	2.5	10	11	11	11	8	11	10	3	7	6.5	7	11	11	11	8
B1[b]	9	3	1	6	1.5	2	3	2	7.5	3.5	2	5	3	4	3.5	3	10	8	10	10	1.5	8	10	10
B1[c]	11	4.5	3	7	3	1	4	4	10	2	5	4	4	3	3.5	5	11	4	11	9	3	9	4	7
C1	10	4.5	4	8	4	3	5	5	7.5	3.5	3	3	2	2	2	2	9	10	9	11	10	7	6	11
D1	1	10	6	9	7	8	7	8.5	6	8.5	8	9.5	7	11	7	8	7	11	5	8	8	10	8	9
E1	2	1	2	1	1.5	4	1	1	1	1	1	1	1	1	1	1	4	1	3	1	6.5	3	7	3
F1	5.5	6	7.5	3	6	10	6	6	9	7	5	6	8	10	8.5	7	8	9	8	6	5	6	1	6
H1	3	7	7.5	4	9	7	9	7	11	8.5	10	8	9.5	9	10	11	6	2	6.5	4	1.5	1	9	4.5
I1	7	9	10	10	10	9	10	10	5	11	9	9.5	9.5	7	8.5	9	2	6	2	3	4	5	3	2
J1	4	8	9	5	8	6	8	8.5	2.5	6	7	7	6	6	6	6	1	5	1	5	6.5	4	2	1
K1	5.5	2	5	2	5	5	2	3	4	5	5	2	5	5	5	4	5	3	4	2	9	2	5	4.5

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a. For changes in weight and dimensions the materials are rated according to the degree of change, the least change being denoted by a rating of 1. For the flexural strength and the flexural modulus of elasticity the materials are rated according to the retention of strength, the material with the greatest increase being rated 1 and that with the greatest decrease being rated 11. For the maximum deflection in flexure the material with the greatest negative change is rated as 1 and that with the greatest positive change as 11.

b. Specimens cut lengthwise.

c. Specimens cut crosswise.

TABLE V.- CONCLUDED

Material Designation	FLEXURAL STRENGTH								MODULUS OF ELASTICITY IN FLEXURE								MAXIMUM DEFLECTION IN FLEXURE								Over-All Rating for All Properties
	Weathering		Accelerated Service Tests					Over-all Rating	Weathering		Accelerated Service Tests					Over-all Rating	Weathering		Accelerated Service Tests					Over-all Rating	
	Out-door	Accel-erated	I	II	III	IV	V		Out-door	Accel-erated	I	II	III	IV	V		Out-door	Accel-erated	I	II	III	IV	V		
	1 yr	120 hr	5 cy	5 cy	5 cy	5 cy	5 cy		1 yr	120 hr	5 cy	5 cy	5 cy	5 cy	5 cy		1 yr	120 hr	5 cy	5 cy	5 cy	5 cy	5 cy		
A1	2	11	11	6	11	11	11	11	8	11	11	10	11	11	11	11	11	11	11	10	11	11	11	11	11
B1[b]	11	9	10	4	6	7	6	9	10	9	8	7	3	4	6	6	6	5	7	8	7	7	9	7	6
B1[c]	10	4	9	5	8.5	10	3	7.5	11	7	9	6	9	9	8	9	10	9.5	10	5.5	9	10	10	10	9
C1	9	2	6	3	3	6	2	2.5	7	3	3	3	6	3	4	3	8	8	8	7	8	5	8	9	4
D1	7	6	7	8	10	9	9	10	3	4	4	5	5	8	5	5	4	7	4	9	4	9	7	6	10
E1	3	5	8	11	4	2	5	4.5	2	5	2	11	1	2	1	2	5	9.5	3	11	10	8	5	8	1.5
F1	8	3	3	7	5	8	4	4.5	4	2	6	4	4	7	3	4	1	2	9	1	3	3	2	2	3
H1	4	7	5	10	8.5	5	10	7.5	5	8	5	9	7	5	9	7.5	2	1	2	2	1	1	1	1	7.5
I1	5	8	4	9	7	4	8	6	6	6	7	8	8	6	7	7.5	7	3	5	3	2	2	4	3	7.5
J1	6	10	2	1	2	3	7	2.5	9	10	10	1	10	10	10	10	3	4	6	4	6	6	6	4	5
K1	1	1	1	2	1	1	1	1	1	1	1	2	2	1	2	1	9	6	1	5.5	5	4	5	5	1.5
	1 yr	240 hr	10 cy	10 cy	10 cy	10 cy	10 cy		1 yr	240 hr	10 cy	10 cy	10 cy	10 cy	10 cy		1 yr	240 hr	10 cy	10 cy	10 cy	10 cy	10 cy		
A1	2	10	11	8	8	11	10	10.5	8	11	11	11	11	11	11	11	11	11	11	10	11	11	11	11	11
B1[b]	11	7	9	4	9	7	5	9	10	8	8	7	6	5	6	7.5	6	4	6	9	2	7	8	6	7
B1[c]	10	5	10	5	11	6	4	8	11	4	9	4	10	7	7	9	10	9	10	6	10	9	10	10	9
C1	9	3	8	3	3	5	2	3.5	7	5	7	3	7	3	3	4	8	6	5	7	9	8	9	8	5
D1	7	6	6	6	7	10	7	7	3	6	3	6	4	9	5	5	4	10	4	8	7	5	6	7	10
E1	3	4	7	11	2	3	3	3.5	2	2	2	10	2	2	2	2	5	8	9	11	4	10	7	9	2
F1	8	2	3	7	5	8	8	5	4	1	5	2	3	8	8	3	1	2	8	1	5	3	4	2	3
H1	4	11	5	10	10	9	11	10.5	5	9	6	9	8	4	9	7.5	2	1	1	4	1	1	1	1	8
I1	5	9	4	9	6	4	6	6	6	7	4	8	5	6	4	6	7	3	3	2	6	4	3	3	6
J1	6	8	2	1	4	2	9	2	9	10	10	1	9	10	10	10	3	5	7	3	8	6	2	5	4
K1	1	1	1	2	1	1	1	1	1	3	1	5	1	1	1	1	9	7	2	5	3	2	5	4	1

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a. For changes in weight and dimensions the materials are rated according to the degree of change, the least change being denoted by a rating of 1. For the flexural strength and the flexural modulus of elasticity the materials are rated according to the retention of strength, the material with the greatest increase being rated 1 and that with the greatest decrease being rated 11. For the maximum deflection in flexure the material with the greatest negative change is rated as 1 and that with the greatest positive change as 11.

b. Specimens cut lengthwise.

c. Specimens cut crosswise.

TABLE VI.– CORRELATION OF LABORATORY AGING PROCEDURES

WITH OUTDOOR WEATHERING[1]

Property	Order of correlation of laboratory aging procedures with outdoor weathering[2]				
	First	Second	Third	Fourth	Fifth
Weight	I-5	I-10	A-120	III-5	A-240
Length and width	I-5	I-10	II-5	A-120	A-480
Thickness	I-5	I-10	III-5	III-10	A-120
Flexural strength	IV-5	III-10	IV-10	V-10	I-10
Flexural modulus of elasticity	III-10	I-5	I-10	III-5	V-10
Deflection in flexure	A-360	V-5	A-240	V-10	II-5

[1]Only the 5- and 10-cycle accelerated service tests are considered since these are the only tests for which data are available for all the properties measured.

[2]The Roman numeral indicates the accelerated service test in Method 6011 of reference 1; the Arabic numeral following it indicates the number of cycles. "A" refers to the Accelerated Weathering Method 6021 of reference 1; the Arabic numeral following it indicates the number of hours.

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TABLE VII.– EQUILIBRIUM MOISTURE CONTENT OF GRADE C PHENOLIC LAMINATE, Il,

AT VARIOUS RELATIVE HUMIDITIES

Temperature (°F)	Relative humidity (percent)	Means or materials to obtain relative humidity	Moisture content (percent)	Time to reach approximate equilibrium[1] (weeks)
77	0	Phosphorus pentoxide	0	25
	50	Conditioning room	3.1	
	76	Sodium chloride[2]	4.6	31
	85	Potassium chloride[2]	5.2	25
	100	Distilled water	7.1	31
100	74	Sodium chloride[2]	4.2	49
	85	Sodium sulfate[2]	5.0	42
	100	Distilled water	6.0	31
140	73	Sodium chloride[2]	4.1	30
	88	Sodium sulfate[2]	5.2	27
	100	Distilled water	6.6	16
				(days)
175	73	Sodium chloride[2]	3.6	4
	88	Sodium sulfate[2]	4.6	7
	100	Distilled water	6.6	6

[1]Specimens were initially conditioned at 77° F and 50-percent relative humidity to weight equilibrium. It is estimated that the specimens are within 2 percent of weight equilibrium at the times indicated.

[2]Saturated aqueous solution.

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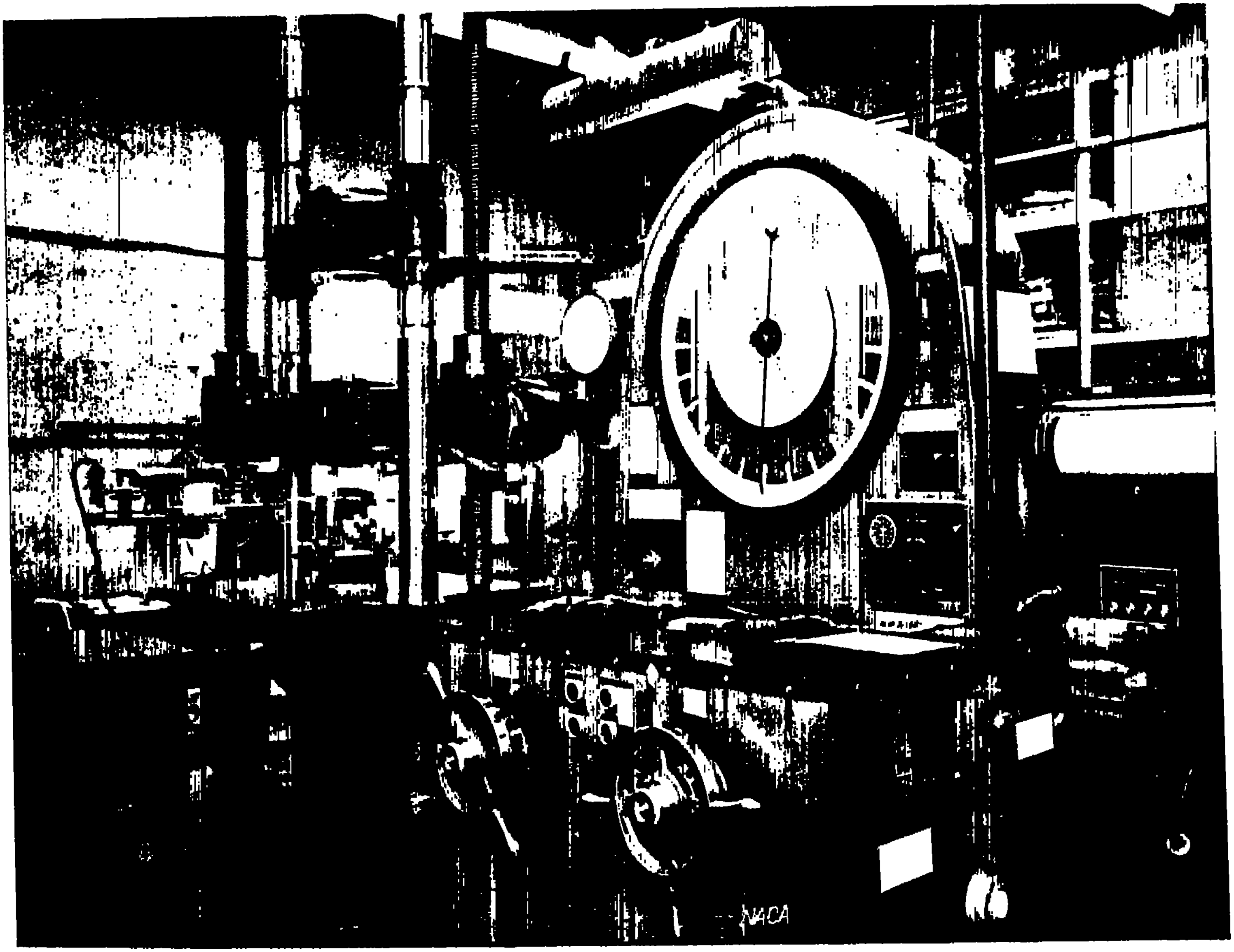


FIGURE 1.- HYDRAULIC UNIVERSAL TESTING MACHINE WITH ELECTRICAL-MECHANICAL EXTENSOMETER AND AUTOGRAPHIC RECORDER.

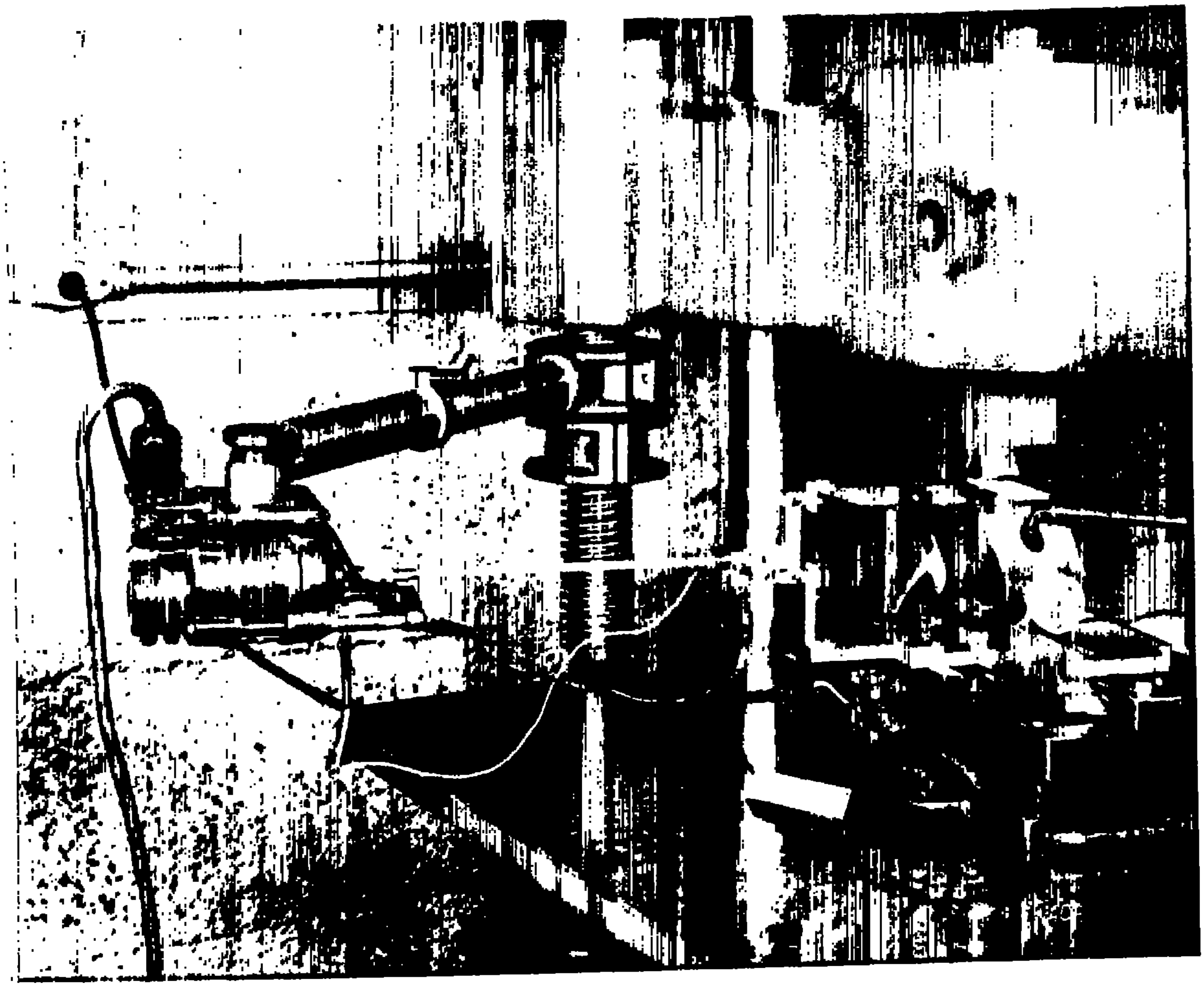


FIGURE 2.- ADJUSTABLE-SPAN FLEXURAL JIG AND EXTENSOMETER.

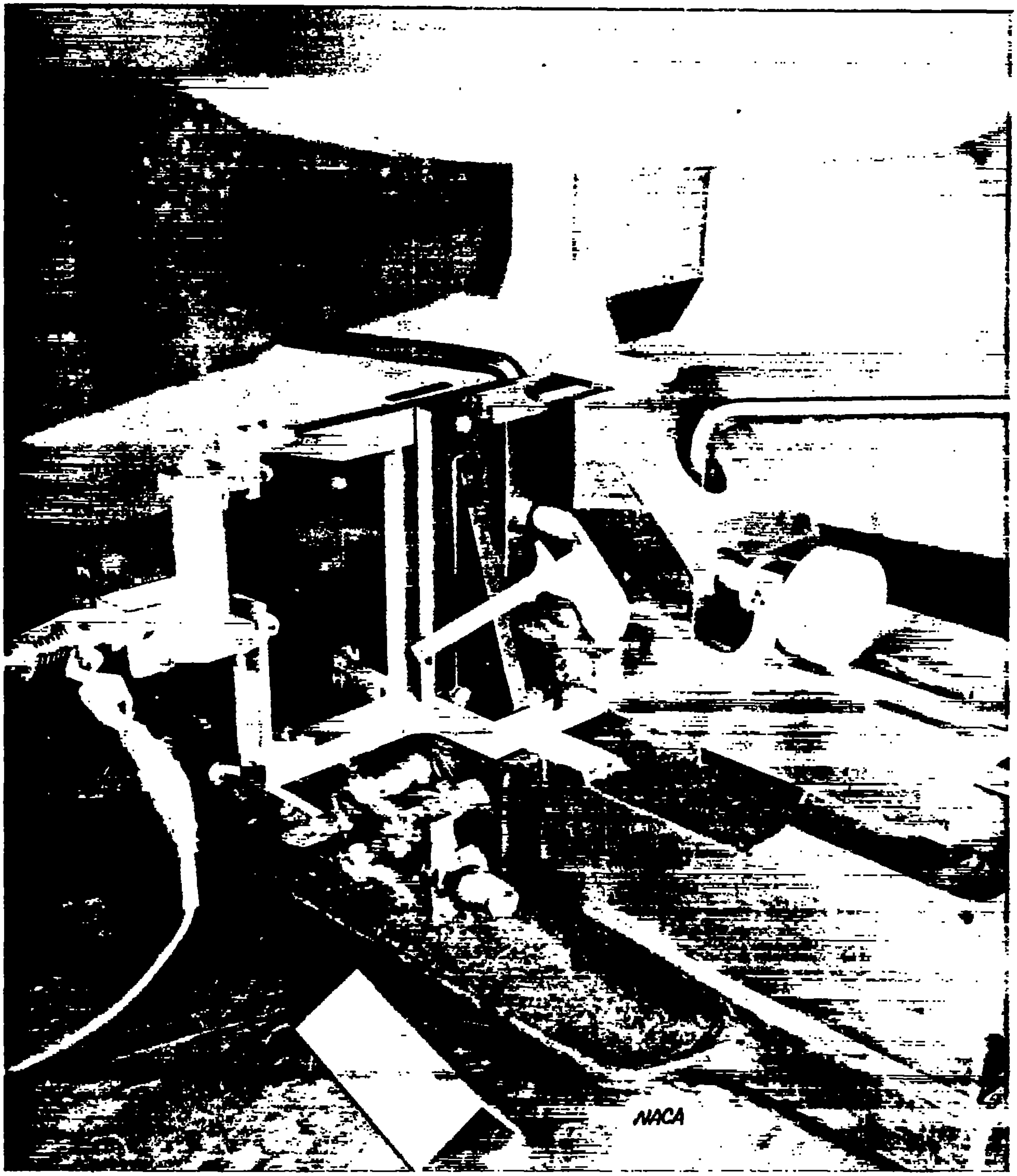
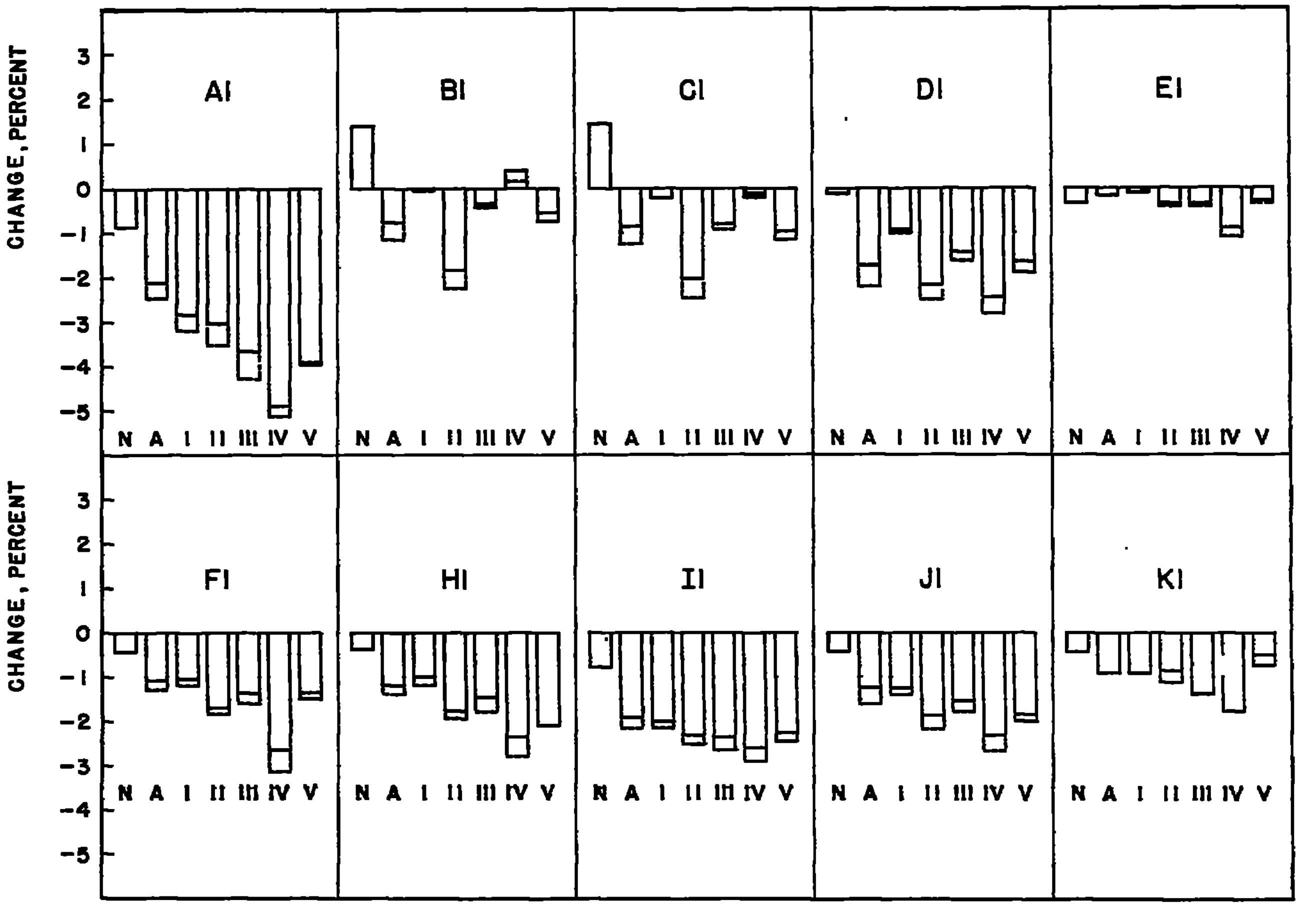


FIGURE 3.- CLOSE-UP VIEW OF ADJUSTABLE-SPAN FLEXURAL JIG AND EXTENSOMETER USED FOR MEASURING DEFLECTIONS OF SPECIMENS IN FLEXURAL TESTS.



MATERIALS

A1. PHENOLIC MACERATED
B1. PHENOLIC PAPER, PARALLEL-PLY
C1. PHENOLIC PAPER, CROSSED-PLY
D1. LIGNIN PAPER
E1. GLASS POLYESTER
F1. MUSLIN POLYESTER
H1. DUCK POLYESTER
I1. GRADE C PHENOLIC
J1. GRADE L PHENOLIC
K1. GRADE AA PHENOLIC

TESTS

N. OUTDOOR WEATHERING, 1 YEAR
A. ACCELERATED WEATHERING, SUNLAMP-FOG, METHOD 6021, FED. SPEC. L-P-406a
SOLID LINE, 120 HOURS
DOTTED LINE, 240 HOURS
I-V. ACCELERATED SERVICE TESTS, METHOD 6011, FED. SPEC. L-P-406a
SOLID LINE, 5 CYCLES
DOTTED LINE, 10 CYCLES

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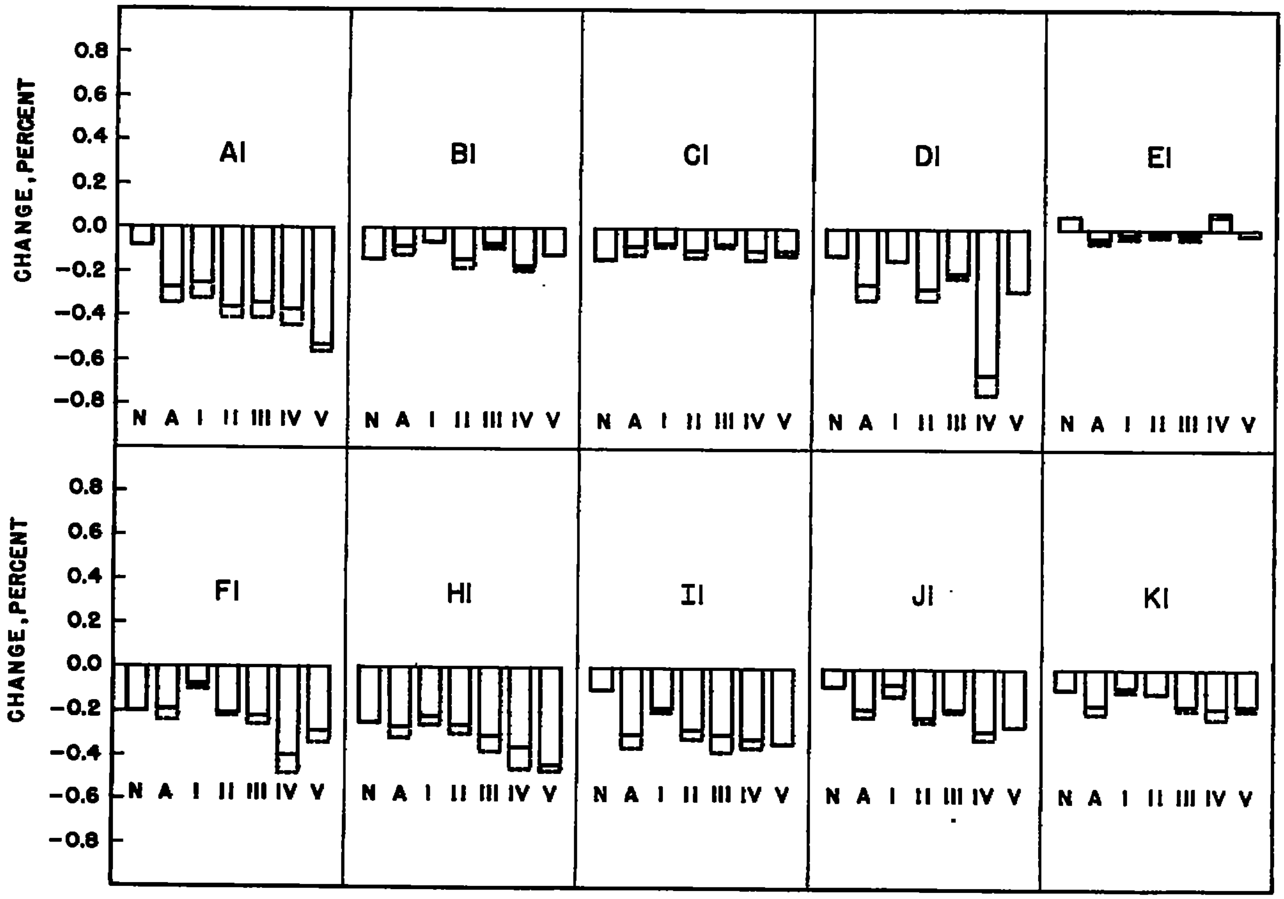
FIGURE 4.- CHANGES IN WEIGHT OF LAMINATES IN WEATHERING AND SERVICE TESTS.



MATERIALS		TESTS	
A1.	PHENOLIC MACERATED	N.	OUTDOOR WEATHERING, 1 YEAR
B1.	PHENOLIC PAPER, PARALLEL-PLY	A.	ACCELERATED WEATHERING, SUNLAMP-FOG, METHOD 6031, FED. SPEC. L-P-406a SOLID LINE, 120 HOURS DOTTED LINE, 240 HOURS
C1.	PHENOLIC PAPER, CROSSED-PLY	I-V.	ACCELERATED SERVICE TESTS, METHOD 6011, FED. SPEC. L-P-406a SOLID LINE, 5 CYCLES DOTTED LINE, 10 CYCLES
D1.	LIGNIN PAPER		
E1.	GLASS POLYESTER		
F1.	MUSLIN POLYESTER		
H1.	DUCK POLYESTER		
I1.	GRADE C PHENOLIC		
J1.	GRADE L PHENOLIC		
K1.	GRADE AA PHENOLIC		

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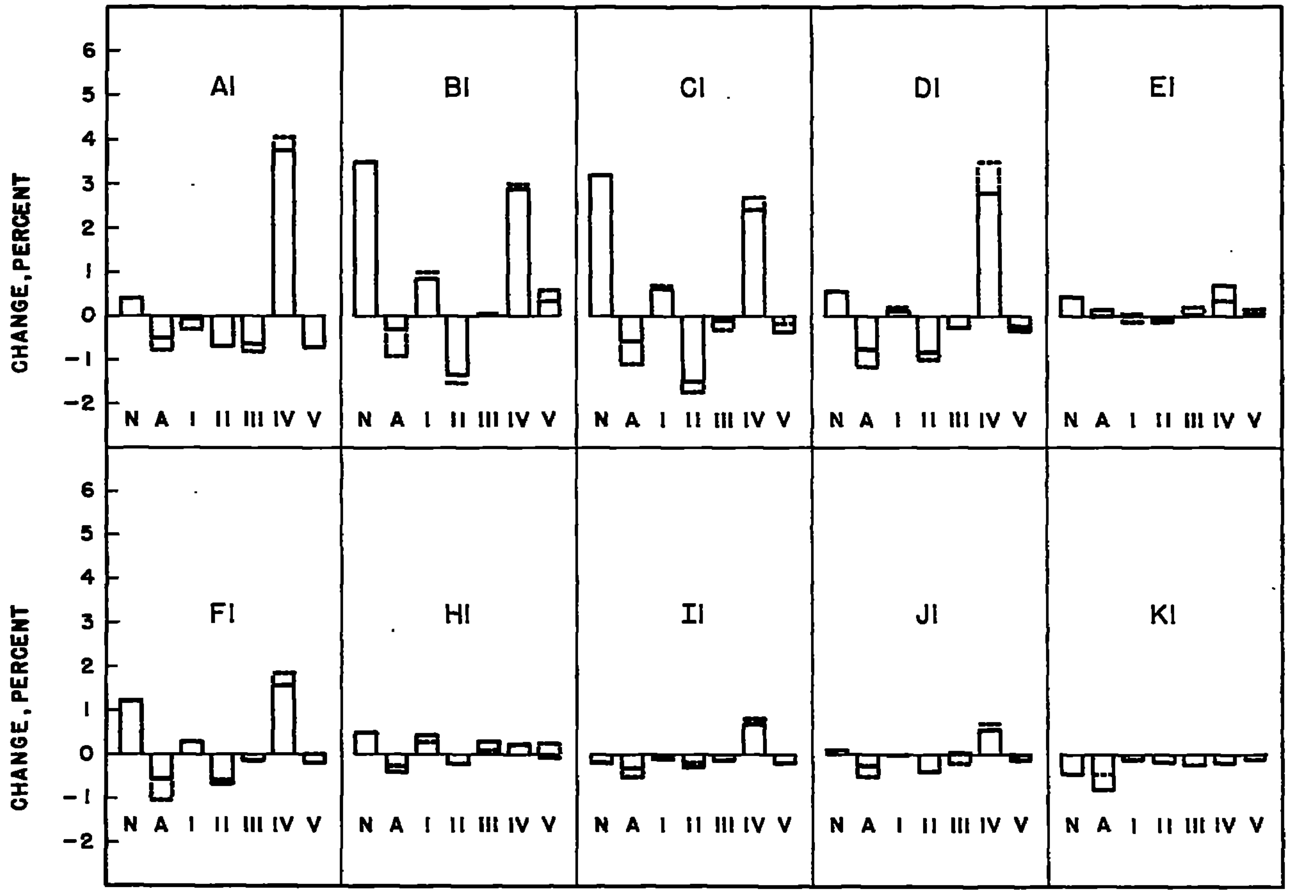
FIGURE 5.- CHANGES IN LENGTH AND WIDTH OF LAMINATES IN WEATHERING AND SERVICE TESTS.



MATERIALS

A1. PHENOLIC MACERATED
B1. PHENOLIC PAPER, PARALLEL-PLY
C1. PHENOLIC PAPER, CROSSED-PLY
D1. LIGNIN PAPER
E1. GLASS POLYESTER
F1. MUSLIN POLYESTER
H1. DUCK POLYESTER
I1. GRADE C PHENOLIC
J1. GRADE L PHENOLIC
K1. GRADE AA PHENOLIC

TESTS

N. OUTDOOR WEATHERING, 1 YEAR
A. ACCELERATED WEATHERING, SUNLAMP-FOG, METHOD 6021, FED. SPEC. L-P-406a
SOLID LINE, 120 HOURS
DOTTED LINE, 240 HOURS
I-V. ACCELERATED SERVICE TESTS, METHOD 6011, FED. SPEC. L-P- 406a
SOLID LINE, 5 CYCLES
DOTTED LINE, 10 CYCLES

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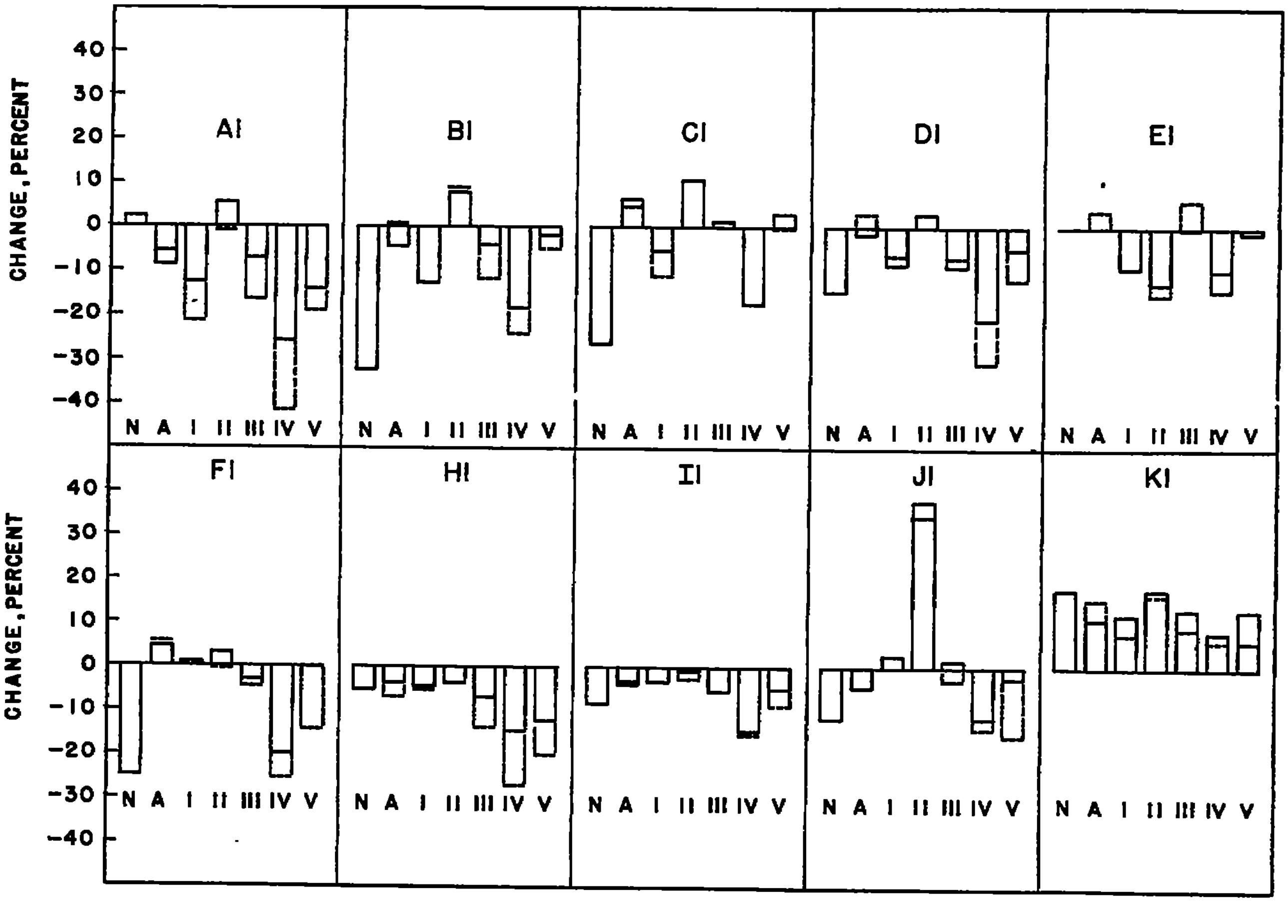
FIGURE 6.- CHANGES IN THICKNESS OF LAMINATES IN WEATHERING AND SERVICE TESTS.



MATERIALS

A1. PHENOLIC MACERATED

B1. PHENOLIC PAPER, PARALLEL-PLY

C1. PHENOLIC PAPER, CROSSED-PLY

D1. LIGNIN PAPER

E1. GLASS POLYESTER

F1. MUSLIN POLYESTER

H1. DUCK POLYESTER

I1. GRADE C PHENOLIC

J1. GRADE L PHENOLIC

K1. GRADE AA PHENOLIC

TESTS

N. OUTDOOR WEATHERING, 1 YEAR

A. ACCELERATED WEATHERING, SUNLAMP-FOG, METHOD 6021, FED. SPEC. L-P-406a

SOLID LINE, 120 HOURS

DOTTED LINE, 240 HOURS

I-V. ACCELERATED SERVICE TESTS, METHOD 6011, FED. SPEC. L-P-406a

SOLID LINE, 5 CYCLES

DOTTED LINE, 10 CYCLES

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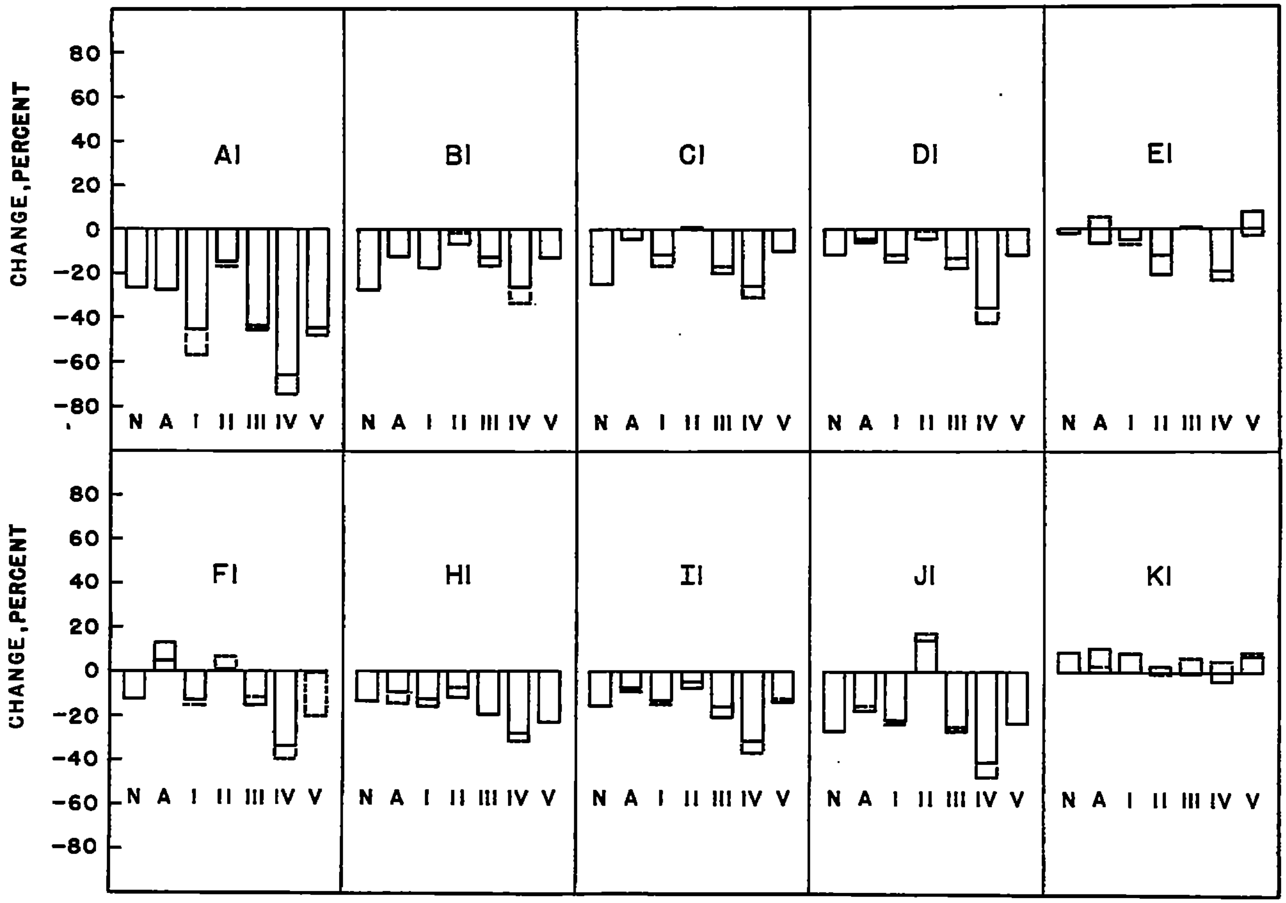
FIGURE 7.- CHANGES IN FLEXURAL STRENGTH OF LAMINATES IN WEATHERING AND SERVICE TESTS.



MATERIALS

A1. PHENOLIC MACERATED

B1. PHENOLIC PAPER, PARALLEL-PLY

C1. PHENOLIC PAPER, CROSSED-PLY

D1. LIGNIN PAPER

E1. GLASS POLYESTER

F1. MUSLIN POLYESTER

H1. DUCK POLYESTER

I1. GRADE C PHENOLIC

J1. GRADE L PHENOLIC

K1. GRADE AA PHENOLIC

TESTS

N. OUTDOOR WEATHERING, 1 YEAR

A. ACCELERATED WEATHERING, SUNLAMP-FOG, METHOD 6021, FED. SPEC. L-P-406a

SOLID LINE, 120 HOURS

DOTTED LINE, 240 HOURS

I-V. ACCELERATED SERVICE TESTS, METHOD 6011, FED. SPEC. L-P-406a

SOLID LINE, 5 CYCLES

DOTTED LINE, 10 CYCLES

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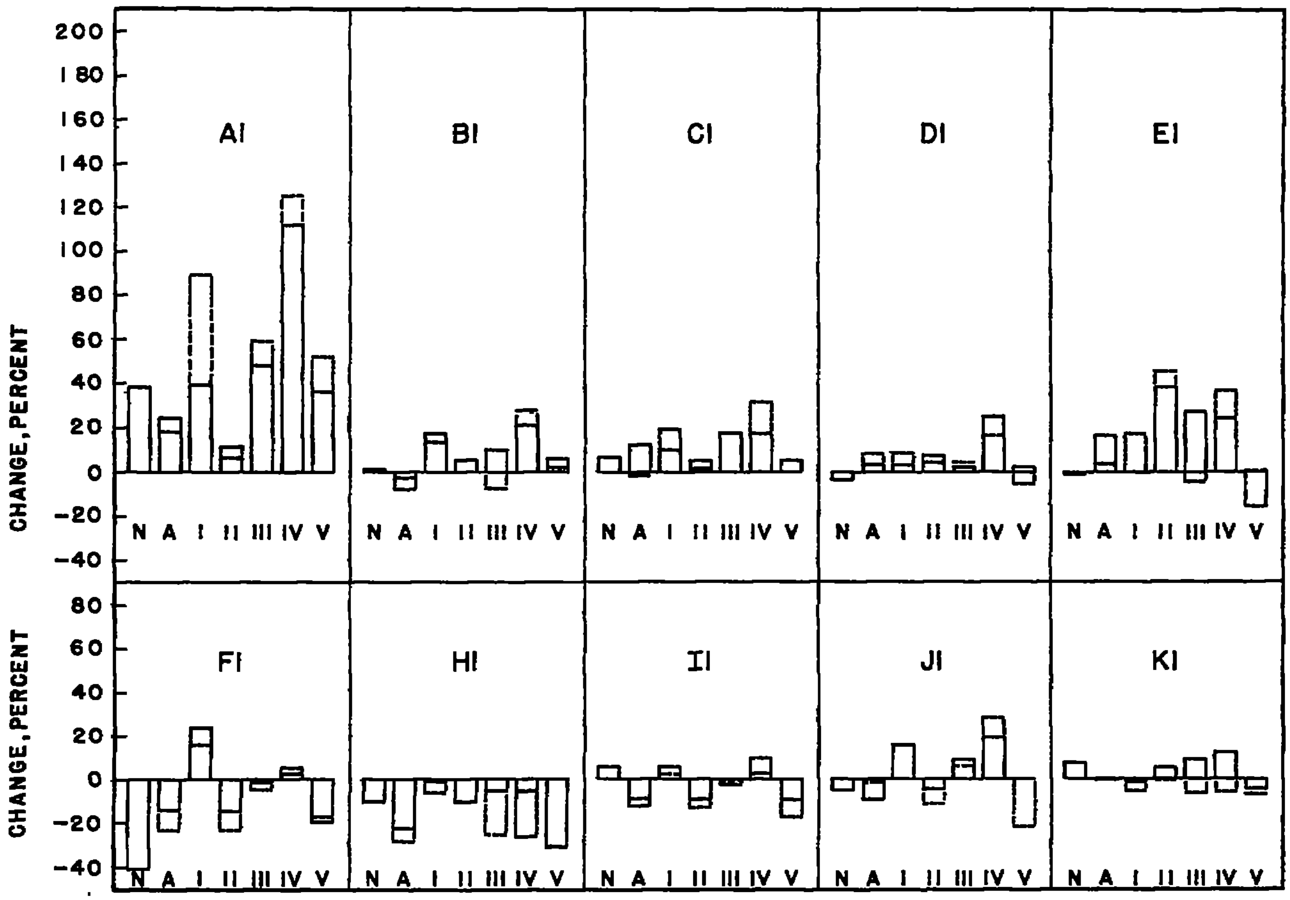
FIGURE 8.- CHANGES IN FLEXURAL MODULUS OF ELASTICITY OF LAMINATES IN WEATHERING AND SERVICE TESTS.



MATERIALS	
A1.	PHENOLIC MACERATED
B1.	PHENOLIC PAPER, PARALLEL-PLY
C1.	PHENOLIC PAPER, CROSSED-PLY
D1.	LIGNIN PAPER
E1.	GLASS POLYESTER
F1.	MUSLIN POLYESTER
H1.	DUCK POLYESTER
I1.	GRADE C PHENOLIC
J1.	GRADE L PHENOLIC
K1.	GRADE AA PHENOLIC

TESTS

N. OUTDOOR WEATHERING, 1 YEAR

A. ACCELERATED WEATHERING, SUNLAMP-FOG, METHOD 6021, FED. SPEC. L-P-406a
- SOLID LINE, 120 HOURS
- DOTTED LINE, 240 HOURS

I-V. ACCELERATED SERVICE TESTS, METHOD 6011, FED. SPEC. L-P-406a
- SOLID LINE, 5 CYCLES
- DOTTED LINE, 10 CYCLES

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FIGURE 9.- CHANGES IN MAXIMUM DEFLECTION IN FLEXURE OF LAMINATES IN WEATHERING AND SERVICE TESTS.

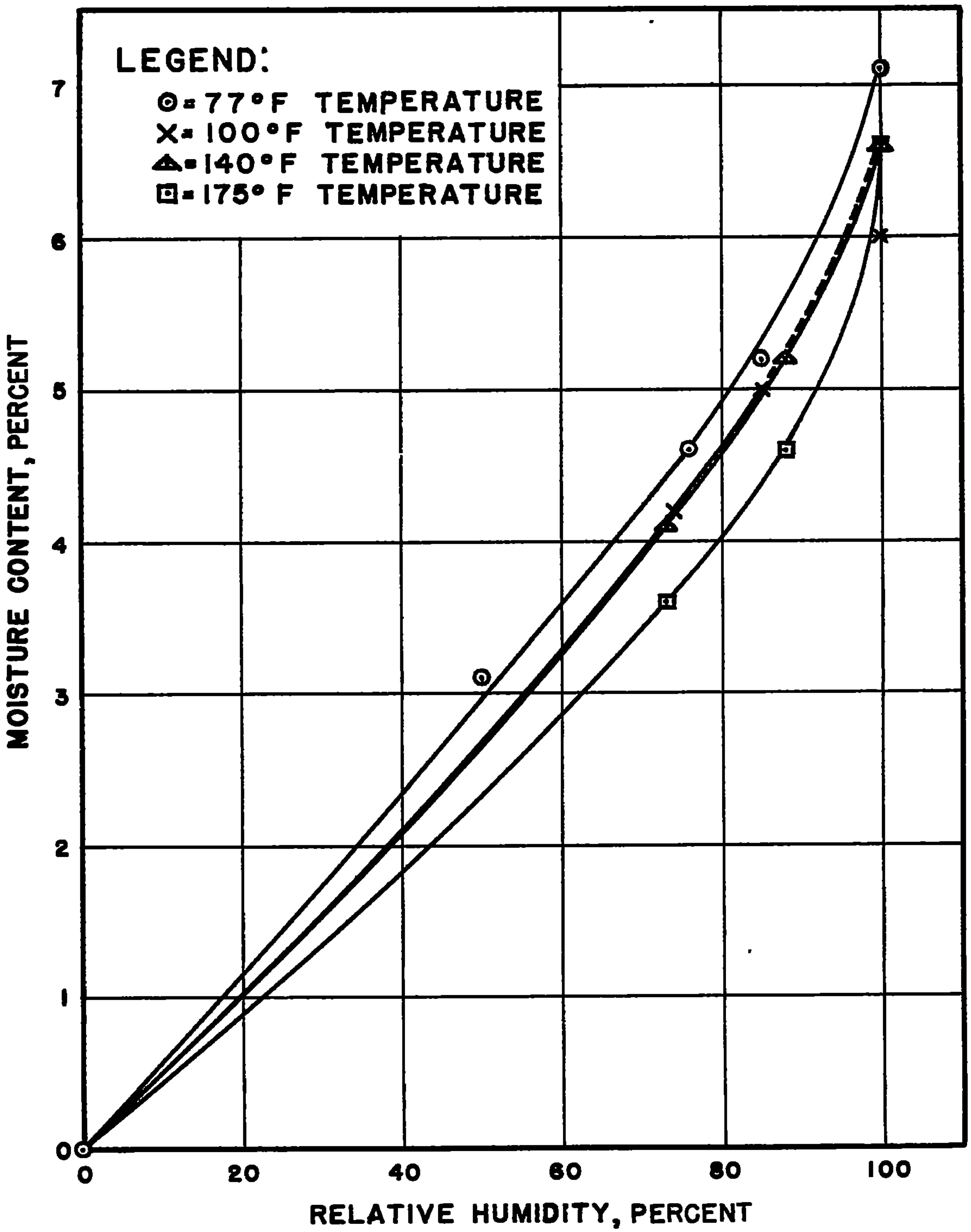

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FIGURE 10.- MOISTURE CONTENT OF GRADE C PHENOLIC LAMINATE AT DIFFERENT RELATIVE HUMIDITIES AND TEMPERATURES.